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introduced to this kind of frogging on the shores of Lake Campbell, near Brookings, S. D. Leopard frogs of all sizes were to be found literally by the thousands. All one has to do is to reach his bare hand into the holes and pull them out by the handfuls. What an opportunity for obtaining large numbers for laboratory use or for examination for parasites! So far as the writer knows, the only use that is made of them in the above-mentioned locality is that picnic parties go out to the lakes and enjoy a mess of frog legs in season.

Thus in brief are a few pointers on frogs and frogging gleaned from the writer's field notebook. They are submitted for publication in the hope that others will find them worth while.

The Industrial Research Movement of To-day.

W. F. Faragher.

The ambition of every healthy business is growth. Whatever may be the chief motive which impels an individual concern towards this goal, it is certain that a desire to render the largest possible measure of service to society is a salient factor in its program of development. For the firm typical of the times, the mercenary aspects of this principle are recessive. With the more general adoption of this method of conducting, results of a revolutionary character will be achieved, and the establishment of our national commercial activities upon an unassailable foundation assured.

The importance to our nation of a fully developed, virile manufacturing activity cannot be overestimated. Not only must the diversified needs of our own people be cared for efficiently, but also the requirements of foreign markets must be supplied in as large measure as is possible in view of the many handicaps which we suffer. We have been too long content to control the balance of trade by the exportation of raw materials and of commodities the value of which has been only slightly increased by fabrication. We should, particularly at this period of readjustment of world commerce, strive to put ourselves in a position to furnish, in competition with the world, articles which have increased value because of their uniqueness in meeting man's requirements or because of the skill and outlay expended in their preparation.

It is not difficult to show that most of our successful and desirable innovations in industry have been developed around invention and scientific experimentation or research. Formerly no close distinctions were drawn between these two functions, as a rule. Very frequently, also, the invention or research was not directly associated with the business which reaped the reward. We may now, however, assert that all properly planned and properly executed research is remunerative. Furthermore, it is now established that any technical business which wishes to expand as it should must in some way avail itself of technical, *i. e.*, chemical and engineering, research. In the sense here intended, research covers all activity which looks toward the application to a given factory process or product of any available chemical or engineering knowledge not currently employed in connection with them.

The business world has for a long time been familiar with various methods of insuring against discontinuance in the face of certain disasters—insurance policies in favor of the company covering the life of an indispensable officer, policies covering bad accounts, and sinking funds accumulated in times of prosperity. It is high time, however, that all of our industrialists know that there is available an insurance of a higher type than any of these—organized research. Not only will such research insure that a business will continue uninterruptedly in the old way, but also that it will expand normally by improving its processes and its products, and also in some cases by finding new uses for its products and byproducts. Organized research is at once an investment and an assurance of future growth and activity.

Although there have always been active centers of research and competent research men imbued with the importance of their labors, the commercial world had, until comparatively recently, failed to see in these agencies the potent instrument for extension which is so greatly needed. The average industrialist, if he were cognizant of these activities at all, regarded them as something wholly academic and consequently of no concern to him. It is true that in the beginning the problems of the majority of these researches were those of pure science. The data which were accumulated were in many instances of the highest quality, and are even now considered to be classical. Work of this character is fundamental and therefore indispensable to all technical business. It is not surprising, however, that in spite of this satisfactory growth in pure science, the recognition of the value of organized industrial research was only slowly realized. Fortunately, there have been from the beginning of our commercial development isolated examples of organized research in industry which proved to be highly successful. The number of these departments had increased relatively very greatly by the beginning of the present century, and the possibilities of industrial research were being considered favorably by a growing circle of our foremost industrial organizations. The old belief that industry can be assisted only by those actively engaged in the productive phases of industry was placed well on the defensive. The newly demonstrated, or rather, slowly established, fact was the adaptability of the research methods and the data of pure science to the problems of industry.

An interesting example, and an extremely valuable one, of a serious attempt to foster the research movement in industry is presented in the work of the Mellon Institute of the University of Pittsburg. This institution is an outgrowth of a department of industrial research established at the University of Kansas in 1907 by the late Dr. Robert Kennedy Duncan. At this time, as indicated above, the desirability of organized research in industry was appreciated. The whole subject of the proper organization of industrial research was so new, however, that progress was still relatively slow. The most successful installations of research laboratories were those of some of our large corporations. There research departments had grown from small beginnings, through the vicissitudes of repeated reorganizations, to positions of first importance to their respective companies. The mutual understanding of industrialist and research worker was still so unsatisfactory, however, that the founding of a department of research by an industrialist was a considerable financial hazard.

Recognizing all of these conditions, Doctor Duncan formulated a plan for introducing individual firms to organized research on their own problems, and for training men educated in the methods of research in pure chemistry to become leaders in their selected fields of technical research. By a fortunate circumstance Doctor Duncan was enabled to inaugurate the work at Kansas soon after he had perfected the fundamental principles of the plan. Briefly stated, the plan provided for the founding of temporary industrial fellowships at the University of Kansas by individuals or corporations who had specific chemical problems the solution of which were needed in industry. By the payment of a fixed sum annually for a period of one or two years the individual or corporation became the donor of such a fellowship. Renewals were possible if agreed upon. Exclusive rights to the data obtained and to the patents issued to the fellow belonged to the donor for a period of years. The selection of the research man, the fellow and the supervision of his work were the duty of Doctor Duncan, and subsequently of a committee of men who knew both the methods of research and those of the commercial world. The function of the University as a creator and distributor of knowledge was preserved by a provision in the contract stating that after a specified time a complete report of each research could be published by the authorities of the University. In this way the interests of all parties to the contract were cared for adequately. A capable research man was thus enabled to carry on work on an important technical problem, under proper guidance and in an atmosphere which tended to stimulate him to his greatest efforts. The advantage of the use of expensive equipment and apparatus was enjoyed at a minimum expense to the donor. With proper regard to the secrecy which had to be observed in the interests of the donor, consultations with trained scientists of the University staff were provided for.

Such was the plan of Doctor Duncan, which he conceived at the meeting of the International Congress of Applied Chemistry in Rome in 1906. Doctor Duncan went to Rome for this meeting after he had made an extended tour of inspection and study of the technical activities of Germany and France.

After his return to the United States Doctor Duncan, who was the scientific editor of the Harper periodicals, published a series of articles on typical American industries in *Harper's Magazine*. In one of these articles, which treated upon the textile industries, Doctor Duncan referred to the large economic waste which was occasioned by the use of inefficient methods in the power laundry and in the textile bleachery. He stated emphatically that the destruction of fabrics was criminal and could be avoided by the discovery through intensive research of proper methods of working. This scathing indictment of the power-laundry industry by the champion of the research ideal made a strong impression upon Mr. E. Ray Speare, who showed his broad-mindedness and progressiveness by requesting Doctor Duncan to outline a plan for inaugurating the suggested research. The support for the work was promised by the Alden Speare's Sons Company, manufacturers of power-laundry supplies. The meeting of an enthusiast in the research ideal with a business man of broad vision was effected. Vigorous correspondence between these two principles perfected the details of the plans which Doctor Duncan had formulated, and the project of temporary industrial fellowship was launched speedily. Within a short time other business establishments availed themselves of the opportunity afforded by Doctor Duncan's enterprise. Researches in the chemistry of baking, of diastatic ferments for pharmaceutical use, of the preparation of casein from buttermilk, of glass for illuminating purposes, of cement and hydrated lime and of petroleum and its products were soon under way. The plan was thus assured of a thorough trial, and all concerned made every effort to insure its success.

After about three years of operation, during which time results were obtained which were satisfactory to all parties concerned, Doctor Duncan was called to the University of Pittsburg to develop his scheme of temporary industrial fellowships on a still larger scale. Besides founding the research department at Pittsburg, Doctor Duncan continued for a year or two to direct the greatly enlarged department at the University of Kansas. By this time, however, the demands of either school had become as large as one man could meet, so Doctor Duncan chose to confine his efforts to the work at Pittsburg. The chief factors leading to this decision were the favorable industrial environment of Pittsburg and the financial support which the project received, strictly upon its merits, from the Mellon brothers, prominent bankers and "captains of industry" of Pittsburg.

The considerable growth of the department of research even at this time called for a greatly enlarged staff of directors, increased laboratory space and valuable special apparatus. In order to place the work of Doctor Duncan on a permanent basis, thereby rendering an invaluable service to the people of the United States through the industries which supply their needs for various commodities, the Mellon brothers donated a sum of money to erect a suitable building to house the research men and the administrative staff, and to endow the institute sufficiently to enable it to meet the expenses of administration, the addition of permanent mechanical equipment and the necessary operating expenses. None of the money paid by donors had been available for any of these purposes, so the gift of Messrs. A. W. and R. B. Mellon was timely, since the institute was demanding more funds than might well be asked for from a single university. The greatly enlarged institute, now housed in one of the finest buildings for laboratory use to be found anywhere, is at once a memorial to Doctor Duncan and to Judge Mellon, father of the Mellon brothers, who was a forward-looking business pioneer of Pittsburg.

The experimental stage of the system of industrial fellowship may fairly be considered to have been passed in February, 1915, when the permanent house was occupied. The number of fellowships in operation at that time was 23, and the number of fellows or research men was 35. The total annual sum contributed by donors then amounted to $65,000. This money paid only the salaries of the research men, the cost of chemicals and special apparatus used in their researches and the traveling expenses incurred in the pursuance of the researches. At the same time the institute was expending annually about one-third of this amount to take care of the members of the permanent staff of directors, the salaries of the office force and the maintenance of building, permanent apparatus, etc.

The soundness of the fellowship scheme is now generally recognized. Forty-seven fellowships are in successful operation, to the support of which $238,245 have been donated. The institute *per se* is expending $65,000 per annum in maintaining the staff and building. The administrative staff now numbers six, and the fellowships, employing about 70 men, are distributed among these directors according to their specialties. The favorable reception of the opportunity to engage in research by this method on the part of our foremost industrialists is attested to by the everincreasing number of fellowships which are offered. At the present time no solicitation of donors is necessary, and there is, in fact, a waiting list of firms desirous of establishing researches. The accepting of these offers is contingent upon providing suitable accommodations in the already crowded building and upon the selection of research men who by temperament, training and experience are peculiarly fitted to undertake the researches. The appeal to the research workers of the country is very strong, and the list of applicants includes not only large numbers of the most promising men who are beginning their careers in research, but also many of the best research workers with established records of sound accomplishment.

During the eight years from March 1, 1911, to March 1, 1919, the total amount of money contributed by industrial firms or donors was $919,745. The institute itself provided during this same period over $330,000. Basing their decisions wholly upon the benefits derived, many donors continue to renew their fellowships, and new firms, after careful investigation of the results obtained by others, are eager to participate in the operation of the system. In many instances firms are instructed in the value of research as a result of their experience at the institute and proceed to install complete research laboratories of their own. Here, then, is one line of proof that properly planned, properly executed research is remunerative.

As a result of the successful work of Mellon Institute some of our universities have inaugurated programs of industrial research. In every instance they have met with the heartiest coöperation from the institute in formulating their plans and in making the changes from the established policy of Mellon Institute which individual circumstances dictate. The field is too large for any one institution, and the pioneers in the work welcome the accession of all units which give promise of helping to establish the research movement in industry. The adoption of similar methods by foreign universities has followed, and the results obtained prove that the system is sound in the new surroundings also.

The unprecedented demands which were made upon our industries as a result of the war have emphasized as nothing else could have done the essential part which research plays in industrial progress. Our shortsightedness in having entered so slowly into industrial research was very quickly made apparent. No time was lost, however, in establishing the laboratories which were needed so greatly. In spite of the difficulties attending such installations, and of the mistakes which were inevitable in proceeding so hurriedly, the coöperation of our men of science and our leading industrialists has resulted in a development which is without equal. The value of the right kind of research is unquestioned. Firm after firm which formerly had nothing to do directly with research is now planning to secure the benefits which are practically assured by the utilization of research methods. The question is no longer one concerning the desirability of research, but rather one of the proper organization of the research activity in a given business. Even the laboring classes now appreciate the fundamental importance of research to the economic life of the country. The resolution indorsing industrial research which was adopted by the delegates to the convention of the American

Federation of Labor at Atlantic City this summer is unique, and will prove to be of first importance to our country. Therein is embodied an idealism as well as a sane, practical program, which are worthy of any group of men whatsoever. The resolution is well worth the consideration of our industrial leaders and deserves the favorable action which it requests of congress. Again, representatives of the 119 national and international unions called together by President Gompers of the American Federation of Labor in conference at Washington during December, 1919, in their impressive bill of rights have inserted the following paragraph:

> "To promote further the production of an adequate supply of the world's needs for use and higher standards of life, we urge that there be established coöperation between the scientists of industry and the representatives of organized workers."

Many of our foremost industrial organizations now have complete departments of research. In practically every instance the research laboratory has proved to be indispensable and its value to the business served is fully appreciated by the whole business organization. As example of highly successful departments of research, we may mention those of the Eastman Kodak Company, Aluminum Company of America, General Electric Company, the National Aniline and Chemical Company, the Du Pont Company, the Westinghouse Electric and Manufacturing Company, the National Carbon Company, the Hercules Powder Company, the United States Steel Corporation, the General Chemical Company, the Barrett Company, and the Goodyear Rubber Company. Many of these concerns consider their research efforts to be not only a benefit to themselves, but also an advantage to their customers, who share in the results of the laboratories' successes through improved products and decreased costs made possible by improvements in processes.

The small business has greater need of research activity than the powerful corporation, on account of the relatively greater overhead per unit of production which the former generally bears. It is imperative, however, that all mistakes in installing a research organization in a small business be obviated. The large concern can weather the disaster of even considerable losses due to faulty organization, but the small business must be assured that its program is sound before it proceeds. Fortunately, several methods are available for small concerns to engage in industrial research. In the first place, a small business may establish its own laboratory. There are numerous instances where this policy has been followed with the most successful results. By way of illustration, we may describe briefly the experience of Leeds-Northrup Company, manufacturers of electrical measuring instruments. In 1912, when the research laboratory was founded, this firm was doing a volume of business of several hundred thousand dollars per year. In laying down the policy of the department, an almost ideal working program was arranged. It is not too much to say that the greatest factors insuring the success of such an undertaking are the selection of the proper personnel and the relationships maintained between the research department and the executive and technical directors of the business. The general policy of the Leeds-Northrup laboratory was decided upon by a committee consisting of the heads of the research, sales, production and engineering departments. The question of problems to be attacked and decisions concerning the completion of certain researches and the discontinuance of others was the province of this committee. Responsibility for the details of the work done rested properly upon the head of the research department and his associates, men trained in the prosecution of research. It is noteworthy, too, that the head of the research laboratory was treated as a reasonable member of the business and was not subordinated to a factory superintendent or to a manager of sales, for example. Complete records of the cost of each research were kept by the accounting department, and each accepted result from the laboratory was credited with its earnings, just as if it were a project submitted from the outside. In seven years the annual expenditures for research have increased from about $10,000 to about $35,000 per year. Within about six years from the start the total credits had equalized the total charges for research, while during the next two years the credit balance increased at a rapidly accelerated rate.

Another method of organizing research which is especially attractive to small concerns is the establishment of a research laboratory or of an industrial fellowship by an association of manufacturers. The latter of these schemes was first proposed and carried out by the Mellon Institute. Subsequently, the National Canners' Association established their own laboratory at Washington. At the present time there are in successful operation at Mellon Institute eight of these association fellowships. The problems dealt with are those of the leather-belting, refractories, sheet-metal, magnesia, asbestos, fiber-board, insecticides and laundry industries. This type of fellowship is particularly valuable, as it enables the institute to be of direct service to large groups of industrial concerns. Moreover, the successful operation of these fellowships gives rise to more stable relations of coöperation among the members of the associations by the introduction of the reciprocal exchange of experience and research results.

Still another method for securing direct benefit from research, which is also particularly applicable to small businesses, is the coöperation of commercial research laboratories. There are at present a number of these laboratories which specialize in problems of industrial research. Specific problems are accepted by them for investigation, or a general study of factory processes and products will be made. Work of this kind is arranged for on the basis of a schedule of fixed fees.

Beside the agencies furthering research which have been mentioned, others have sprung up which promise to contribute valuable results. During the war the Council of National Defense provided a useful organization which made considerable progress towards introducing research methods into industry and standardizing the methods of organizing research projects in industry. As a result of the activities of the reorganized National Research Council it has been shown that in spite of the substantial progress which research has made in this country, the program is still in its initial stages. Of the 275,000 manufacturing concerns in the country, fewer than one-fourth of one per cent have laboratories of any description. Only half of these laboratories are what they should be, while the number of research laboratories is pitifully small. The new function of the Research Council is to assist in organizing group research undertakings. One project under way is the establishment of a research laboratory for investigating alloys. As at present planned, the contributing members are to be largely manufacturers who need alloys with special properties, rather than those who make alloys. One hundred members, each contributing $100 annually for five years, are considered necessary to insure the success of the project. In a similar way, other groups of industrialists are being interested in research with good prospects of success.

Renewed interest in research is being displayed also by certain departments of the government. Budgets for research activities are provided for on an enlarged scale in the deficiency bill now under consideration by congress. The total for industrial research is $250,000. A special bill to defray the costs of investigation of the production of oil and other products from oil shale has been proposed by Senator Henderson, of Nevada. After a careful review of the situation, passage of the bill or of a similar one was recommended by Secretary Lane, to whom the above bill was referred for a report by the senate committee on mines and mining. Although the government bureaus have been active and successful in research work in the past, the demands for the present are insistent for their enlarged participation in industrial research.

A further example of group research is furnished by an announcement of the recently organized Petroleum Institute. This association is composed of the executive officers and of the principal technical directors of the prominent companies of the petroleum industry. Their program of research, which is to be started at once, calls for the expenditure of $500,000 annually. Besides the technology problems of the industry, such as the improvement of methods of distillation and refining, and the recovery of acids used in the refining of distillates, the institute plans to study the economic and statistical phases of the industry also. The character of the men supporting the project and the ample funds which the institute is providing insure that not only the petroleum industry but also the public will receive large benefits from this undertaking.

Practically all of the methods of conducting research in industry which have been described as important ones in the industrial life of the United States are being utilized in foreign countries. England, France, Japan and Canada are particularly active in this line of work. Germany had early taken advantage of research in her industries and will certainly resume the practice as soon as conditions become at all settled. In England and Japan, at least, the movement is being assisted in certain instances by the governments in a way which amounts practically to a subsidy. With such keen rivals, we must develop our own research projects to the fullest possible extent.

Any of the research organizations which have been mentioned, and any others which may be developed, call for careful consideration of costs. Obviously, every individual research problem engaged in cannot show a profit to the company concerned. Neither does every advertising campaign nor every change in factory processes developed in the old way bring returns. All of the data at hand, however, prove that, considered as a department, the efficient research organization is an asset.

During the year 1918 there was expended for chemical laboratory research alone by American industrialists about $10,000,000. It is impossible to state how much more was expended in experimentation in the factories themselves. As a rough guide to the expenditure which is required to install a chemical laboratory, it may be taken that the first cost of the laboratory will be about $3,500 per scientific worker employed. The annual cost of maintenance of such a laboratory is probably about the same amount per man, on the average.

As is the case in other departments of an organized business, the greatest problem in research administration is the securing of qualified investigators. The failure of the research organization in a given instance is no indictment of the system of research, but rather of the individual director of research or of the scheme of organization under which he was compelled to work. The newness of research activity has already begun to pass and the problem of training research men is being met more and more thoroughly by our schools. Capitalization of the fund of experience already acquired and the increasing supply of properly trained research men now make possible the founding of adequate research departments with no considerable element of risk.

Finally, our universities or technical schools—although in a manner awakened to the importance of this research movement—have still a long way to go. There is no reason why every such school should not perform the functions of the Mellon Institute to a greater or less extent. The academic viewpoint of the ordinary college professor must be changed and such schools be led to realize the great opportunity offered them of joining science with business in a union that will be happy for both.